 Name: ________________________

Section 1: Multiple Choice. 12 questions, 3 points each.

Instructions: For the following questions, circle the answer on the exam sheet **and** bubble in the correct answer on your Scantron sheet. There is **only one** correct answer per problem, so for each question **fill in one bubble on your Scantron form.**

1.) You are taking test version **A**. Please fill in bubble "**A**" on your Scantron sheet.

2.) Given a constant CO_2(g) pressure of 1 atm over a vessel of water, which of the following **will not** increase the equilibrium concentration of CO_2(aq) in the water? Note: CO_2(g) dissolving in water is an exothermic process.

- **A)** Decrease the temperature of the water.
- **B)** Increase the amount of water.
- **C)** Increase the pH.
- **D)** Increase the partial pressure of CO_2(g) from 1 atm to 2 atm.
- **E)** All will increase the concentration.

3.) Which of the following pairs will undergo a spontaneous oxidation/reduction reaction?

A) Zn(s), Cd^{2+} **B)** Ag(s), Cd^{2+} **C)** Li^+, Br^-
D) Zn^{2+}, Au^+ **E)** Ag(s), Ag^+

4.) For which process or reaction is $\Delta S°$ expected to be positive?

- **A)** I_2(g) ------> I_2(s)
- **B)** CO_2(g) + 2 H_2O(λ) ------> H_3O^+(aq) + HCO_3^-(aq)
- **C)** CH_3OH(g) + 3/2 O_2(g) ------> CO_2(g) + 2 H_2O(g)
- **D)** O_2(g) + SO (g) ------> SO_3(g)
- **E)** 2 Mg(s) + CO_2(g) ------> 2 MgO(s) + C(s)

5.) A Zn | Zn^{2+} || Co^{2+} | Co galvanic cell is constructed in which the standard cell voltage, $\Delta\varepsilon°$, is 0.48 V. What is the free energy change at 25 °C (in kJ) per mole of Zn lost at the anode, if all concentrations remain at 1.0 M throughout the process?

A) -6053 **B)** -92.6 **C)** -46.3 **D)** 46.3 **E)** 92.6

6.) Which of the following ***cannot*** occur at the same time?

- **A)** $\Delta S_{sys} > 0$ and $\Delta S_{surr} < 0$
- **B)** $\Delta S_{sys} = 0$ and $\Delta S_{surr} > 0$
- **C)** $\Delta S_{sys} < 0$ and $\Delta S_{surr} > 0$
- **D)** $\Delta S_{sys} > 0$ and $\Delta S_{surr} > 0$
- **E)** All of these can occur at the same time.

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7-10. In the next four problems, choose which of the following five graphs best describes the behaviors listed below.

7.) Energy of a photon as a function of its wavelength.

8.) Mass of $Mg(OH)_2(s)$ precipitate ($K_{sp}=5.6\text{x}10^{-12}$) in water as a function of moles of strong acid added.

9.) ln(K) as a function of $\frac{1}{T}$ for an **endothermic** reaction.

10.) $\Delta\mathcal{E}°$ for the cell $Zn|Zn^{2+}||Ag^{+}|Ag$ as a function of the mass of the Ag electrode used. Assume that $[Zn^{2+}] = [Ag^{+}] = 1.0$ M.

11-12. Answer the next two problems using the following five choices:

A) Spontaneous at all temperatures.
B) Spontaneous at no temperature.
C) Spontaneous at low temperatures, but not at high temperatures.
D) Spontaneous at high temperatures, but not at low temperatures.
E) Spontaneous only at 100° C.

11.) $2\ H_2(g)\ +\ O_2(g)$ ------> $2\ H_2O(g)$. ($\Delta H°<0$; $\Delta S°<0$)

12.) $C_6H_{12}O_6(s)\ +\ 6\ O_2(g)$ ------> $6\ H_2O(g)\ +\ 6\ CO_2(g)$. ($\Delta H°<0$; $\Delta S°>0$)

13.) For the vaporization of bromine, $Br_2(\lambda)$ $Br_2(g)$, $\Delta H°=31$ kJ•mol^{-1} and $\Delta S°=93$ J•mol^{-1}•K^{-1}. Assuming that ΔH° and ΔS° are invariant with temperature, what is the boiling point of $Br_2(\lambda)$?

A) 298 K **B)** 300 K **C)** 333 K **D)** 373 K **E)** Can't determine.

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Section 2: ***What's Wrong*****.** 4 questions, 6 points each.

For this section, in no more than twenty words per response, **explain** what is wrong with the following pictures. **Note: only the first 20 words of each answer will be read!**

1.) A galvanic cell which utilizes the potential difference between Au and Ag:

2.) For the photoionization of a metal:

3.) For the addition of AgCl(s) to 100 mL of water:

4.) For the following two systems of gas molecules:

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Section 3: Short Answer. 5 questions, 65 points total.

Answer the following five short answer questions. Partial credit will be given, so show your work whenever possible. Your final answers **must** be written in the boxes provided.

1.) (12 points) Up to 0.0432 grams of silver dichromate ($Ag_2Cr_2O_7$; MW=432 g•mol^{-1}) will dissolve in 1.00 L of water at 25° C to form Ag^+ and $Cr_2O_7^{2-}$.

a.) Calculate the solubility product constant, K_{sp}, for silver dichromate at 25° C.

b.) Suppose $AgNO_3$(s), which dissociates completely, is added to the above solution until the Ag^+ concentration reaches 0.10 M. How many grams of $Ag_2Cr_2O_7$(s) precipitate will form? Assume the volume remains 1.00 L.

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2.) (12 points) Consider a monatomic ideal gas at a volume of 2 L which is held at constant temperature. The gas is reversibly compressed using a piston until it reaches a volume of 1 L.

For each quantity below, indicate (by checking the box) whether it is =0, >0, or <0 for the overall isothermal compression process.

Quantity	**= 0**	**> 0**	**< 0**
ΔP_{sys}			
ΔV_{sys}			
ΔT_{sys}			
Δn_{sys}			
w			
q			
ΔE_{sys}			
ΔE_{surr}			
ΔE_{tot}			
ΔS_{sys}			
ΔS_{surr}			
ΔS_{tot}			

3.) (15 points) For a lecture demo, Lonnie creates a galvanic cell by placing a cadmium electrode in a 1.0 M solution of cadmium nitrate ($Cd(NO_3)_2$) and a titanium electrode in a 1.0 M solution of titanium nitrate ($Ti(NO_3)_3$), both at 25° C. To complete the circuit, the solutions are connected by a salt bridge and the electrodes are connected by a wire.

a.) Lonnie measures the voltage across the cell and determines it to be 1.60 V. He also notices that the titanium electrode is growing larger. What is the standard reduction potential, ε°, for Ti^{3+} [$Ti^{3+} + 3e^- \text{------->} Ti(s)$]?

b.) Into which solution are the **negative** ions from the salt bridge flowing? Explain your answer.

c.) At the Tuesday lecture, Head TA Dave Laws tries to set up the galvanic cell, but accidentally spills a large amount of distilled water into one of the solutions. This causes the voltage measured to be **higher** than 1.60 V. Which solution did Dave accidentally spill the water into? Explain your answer.

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4.) (11 points) A student is doing a research project on the thermodynamics of dissolving sucrose, $C_{12}H_{22}O_{11}$, in water according to the equation:

$$C_{12}H_{22}O_{11}(s) \;\square\; C_{12}H_{22}O_{11}(aq)$$

In her first experiment, the student takes 34.2 g of sucrose (MW=342 $g \cdot mol^{-1}$) and completely dissolves it in 1.00 L of water inside a calorimeter which is initially at 25.0 °C. Once the sucrose is dissolved, she measures the temperature to be 24.5 °C.

a.) What is the enthalpy change, ΔH, in $kJ \cdot mol^{-1}$ for this process? Remember that for a calorimeter, you can use the equation: $q = -mC_p\Delta T$, where the specific heat for **water,** $C_p = 4.184\ J \cdot g^{-1} \cdot K^{-1}$.

b.) How many grams of sucrose would the student have to dissolve in 1.00 L of water in order to lower the temperature from 25.0 °C to 23.5 °C?

c.) Based on your answer to part (a), would you predict the K for the dissolution of sucrose in 50 °C water to be larger, smaller, or the same as the K for the dissolution of sucrose in 25 °C water? Explain your answer in 20 words or less.

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5.) (15 points) Two metals, metal A and metal B, are irradiated with green light at 500 nm. Metal A ejects an electron with a speed of 5.0×10^5 m•s^{-1}, while metal B ejects an electron with a speed of 3.4×10^5 m•s^{-1}.

a.) Which metal, A or B, has the larger work function, Φ? Explain your answer.

b.) If you wanted to eject an electron from metal B with exactly twice (2x) the kinetic energy as in part **a.)**, which of the following light sources might be used? Circle your answer and explain your reasoning in 20 words or less.

Light Source:	**Operating Wavelengths:**
Krypton-Fluorine laser:	≤250 nm
Pulsed dye laser	250 nm to 500 nm
Argon ion laser:	500 nm to 1100 nm

c.) If metal A is silver, which of the following could be metal B? Circle your answer and explain your reasoning in 20 words or less. **Hint:** think of ejecting an electron as an *oxidation* process.

Gold Lithium

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Half Reaction	**ε° (V)**
$Au^+ + e^-$ -----> $Au(s)$	1.68
$Br_2(\lambda) + 2e^-$ -----> $2 Br^-$	1.07
$Ag^+ + e^-$ -----> $Ag(s)$	0.80
2 H+ + $2e^-$ -----> $H_2(g)$	0.00
$Cd^{2+} + 2e^-$ -----> $Cd(s)$	-0.40
$Zn^{2+} + 2e^-$ -----> $Zn(s)$	-.076
$Mg^{2+} + 2e^-$ -----> $Mg(s)$	-2.38
$Li^+ + e^-$ -----> $Li(s)$	-3.05

Possibly Useful Information

$S = k_B \ln\Omega$

$\Delta H_{sys} = q = nC_p\Delta T$ at constant pressure.

$\Delta G = \Delta H - T\Delta S$

$\Delta G° = -RT\ln K$

$\Delta G = \Delta G° + RT\ln Q$

$$\Delta S_{sys} = nR\ln\frac{V_2}{V_1}$$

$\Delta S_{tot} = \Delta S_{sys} + \Delta S_{surr}$

$\Delta E_{tot} = \Delta E_{sys} + \Delta E_{surr}$

$\Delta E = q + w$

$w = -P_{ext}\Delta V$

$$\Delta S_{surr} = -\frac{q_{rev}}{T}$$

$\Delta G° = -nF\Delta\varepsilon°$, where F=96,485 C • mol^{-1}

Absolute T(K) = T(°C) + 273.15

$PV = nRT$

$$\Delta H^o_{form} = \Delta H^o_{products} - \Delta H^o_{reactants}$$

$R = 0.0821$ L • atm • mol^{-1} • K^{-1}

$R = 8.31$ J • mol^{-1} • K^{-1}

Chemistry is fun.

$$E = \frac{hc}{\lambda}$$

$E_{electron} = E_{photon} - \Phi$

$$E_{kinetic} = \frac{mv^2}{2}$$

$\Delta H = \Delta E + \Delta(PV)$

$$\ln K = -\frac{\Delta H°}{R}\left(\frac{1}{T}\right) + \frac{\Delta S°}{R}$$